Visualizing Electrons in ATLAS

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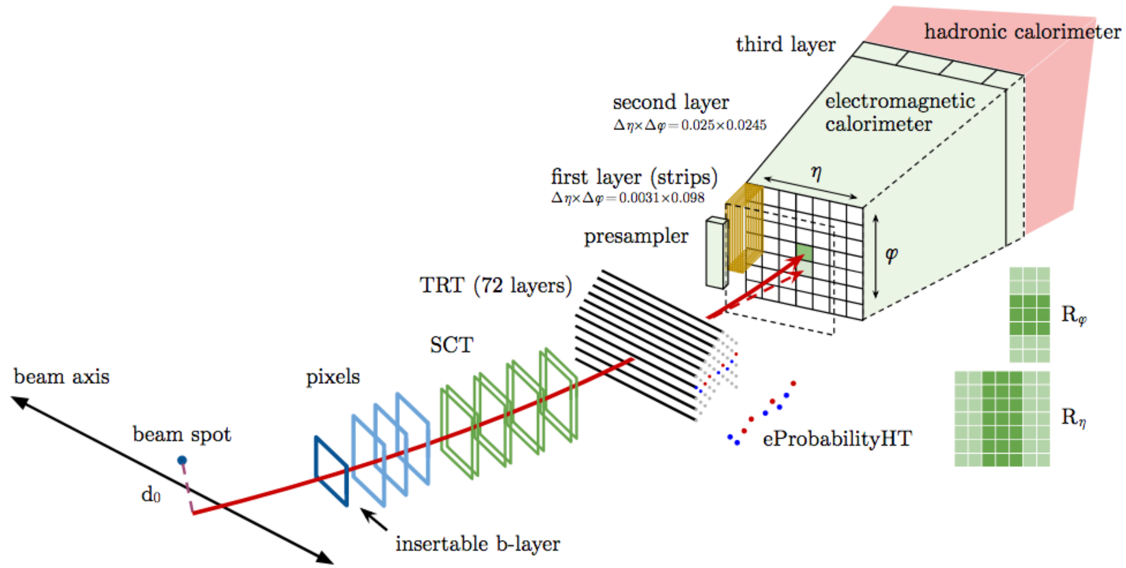
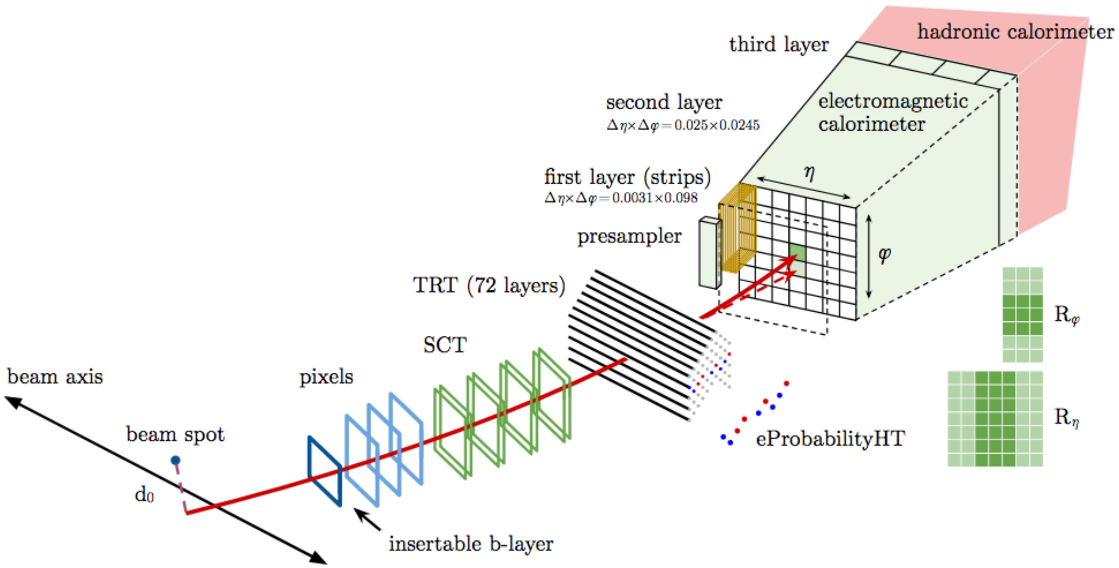
Electrons In ATLAS



BASICS

- Electrons are massive and charged → they interact with the tracker and calorimeter
- Create tracks and energy clusters → easy to reconstruct
- Interactions are well understood → can estimate energy well

Electrons In ATLAS



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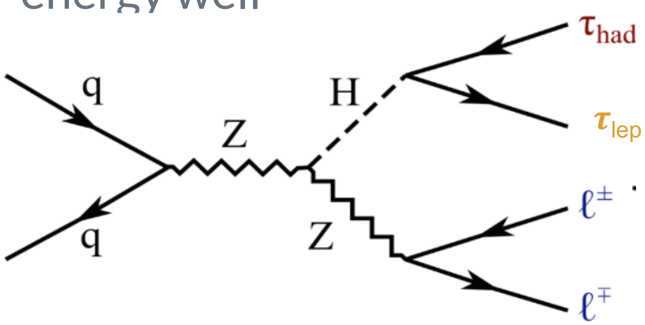
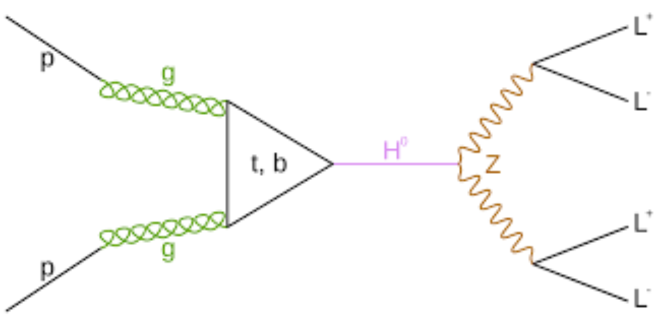




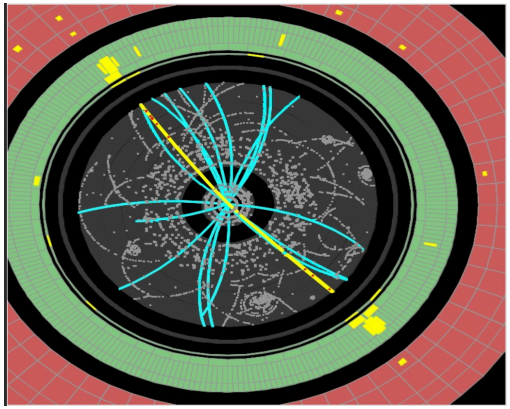
USE IN ATLAS

- Efficient triggers and ID → analyses with electrons benefit from improved background rejection
- Accurate reconstruction → final states with electrons have reduced systematics
- Extending the range of electron algorithms → more physics searches are possible
- But room for improvement!

Electron Software

Reconstruction

- Create clusters from energy deposits in EM Calo
- Create tracks from hits in the inner detector
- Form electron candidates by matching tracks to clusters
  - Based on energy, location, and hit types



Electron Software

Reconstruction → Identification

Reconstruction

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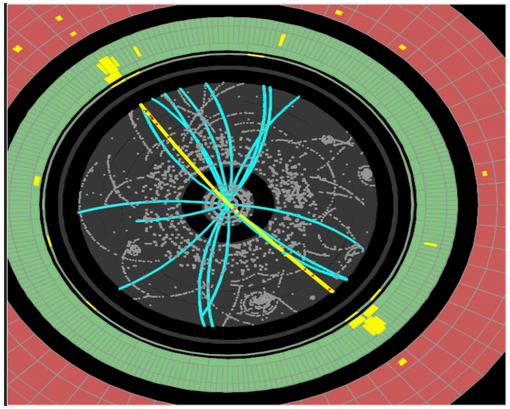
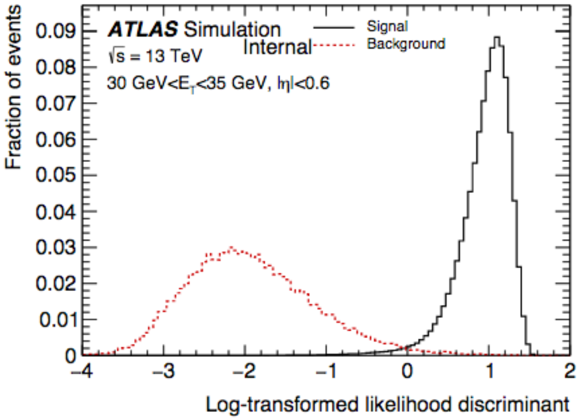
Identification

- Calculate physics motivated variables
- Calculate Likelihood
  - Formed from PDFs of electron variables
- Evaluate LH score compared to recommendations





Electron Software

Reconstruction	Identification	Energy Regression

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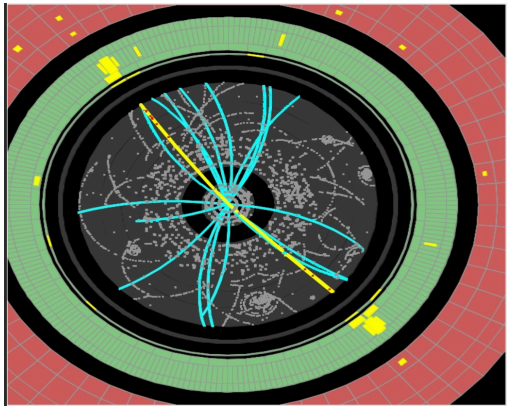
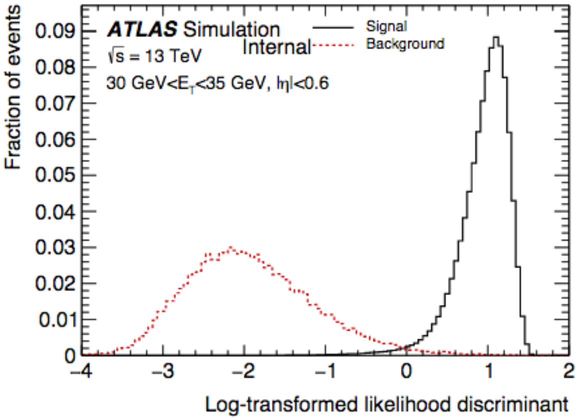
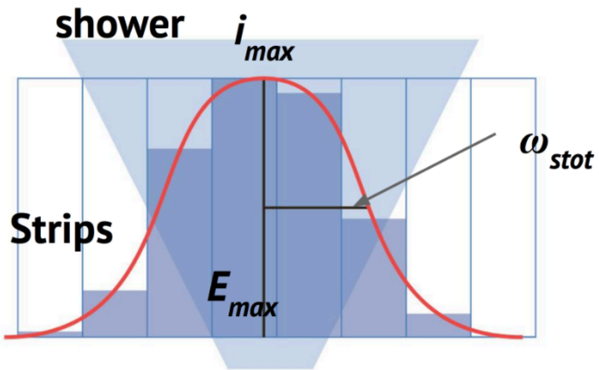
Energy Regression

- Calculate potential loss due to bremsstrahlung
- Consider cluster width variability and electronics gain
- Combine effects to get corrected electron energy

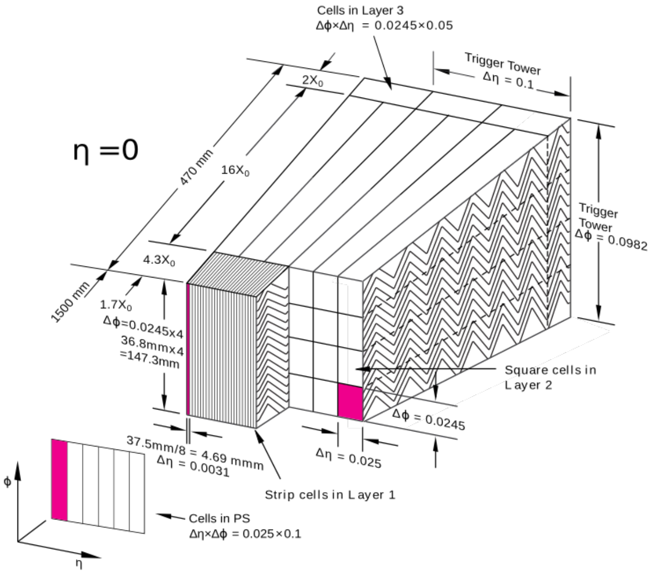


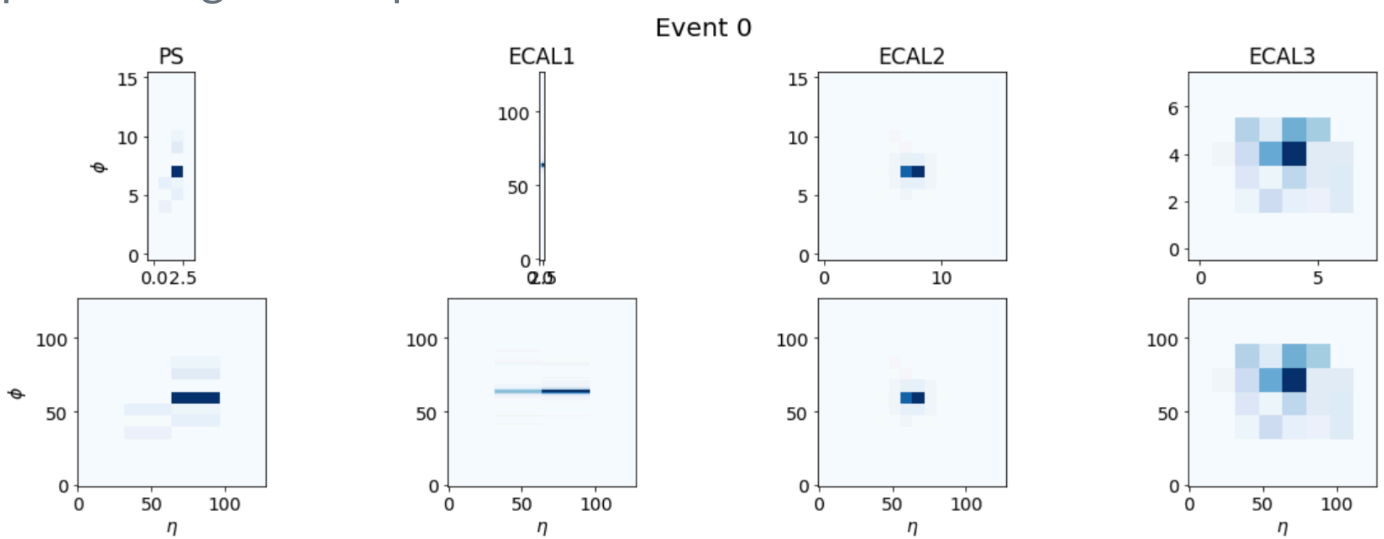




A New Way to Look at Electrons

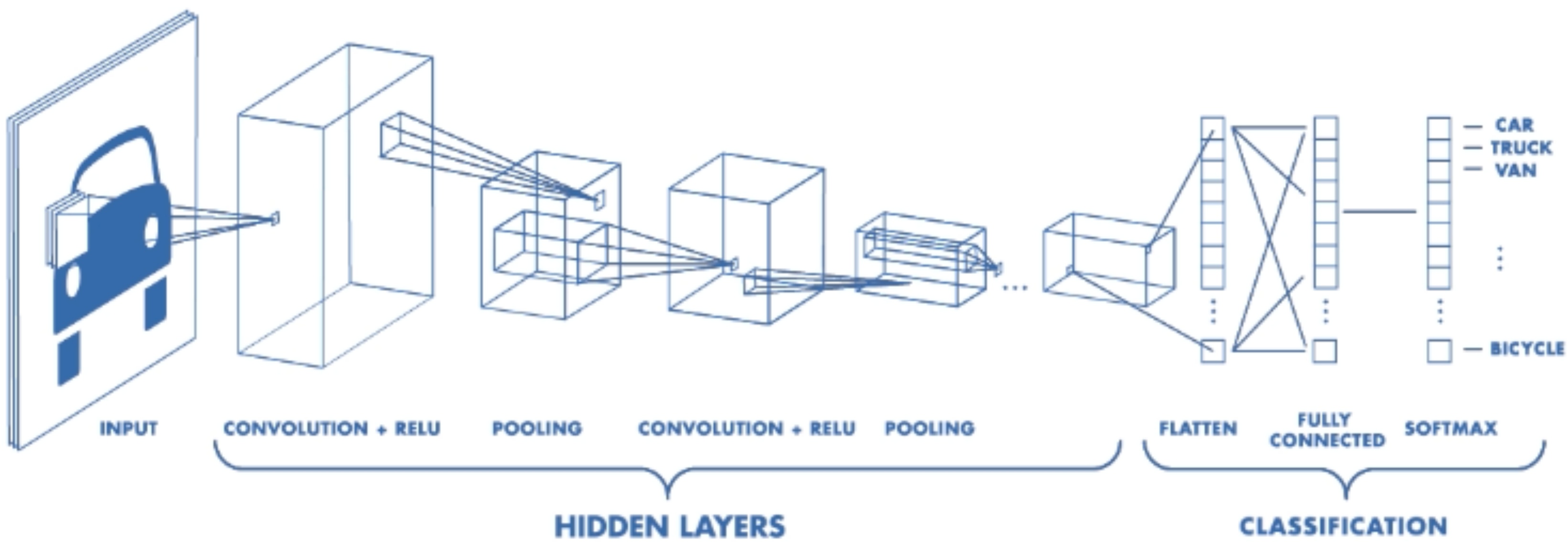
- Most electron algorithms currently combine calculated variables
  - MVA techniques can exploit smaller differences in distributions
  - But potential for information loss is still present
- We could instead look at direct read-outs of the detector
  - One way to represent this information is images
  - Consider ‘unrolling’ the calorimeter and representing cells as pixels





Computer Vision

- Convolutional Neural Networks (CNNs) are a popular ML technique for processing images
  1. 'Read in' images as a matrix of pixels with numerical values
  2. Convolve the image with filters to create multiple high-level representations of the original image
  3. Use these representations as input to classification or other task



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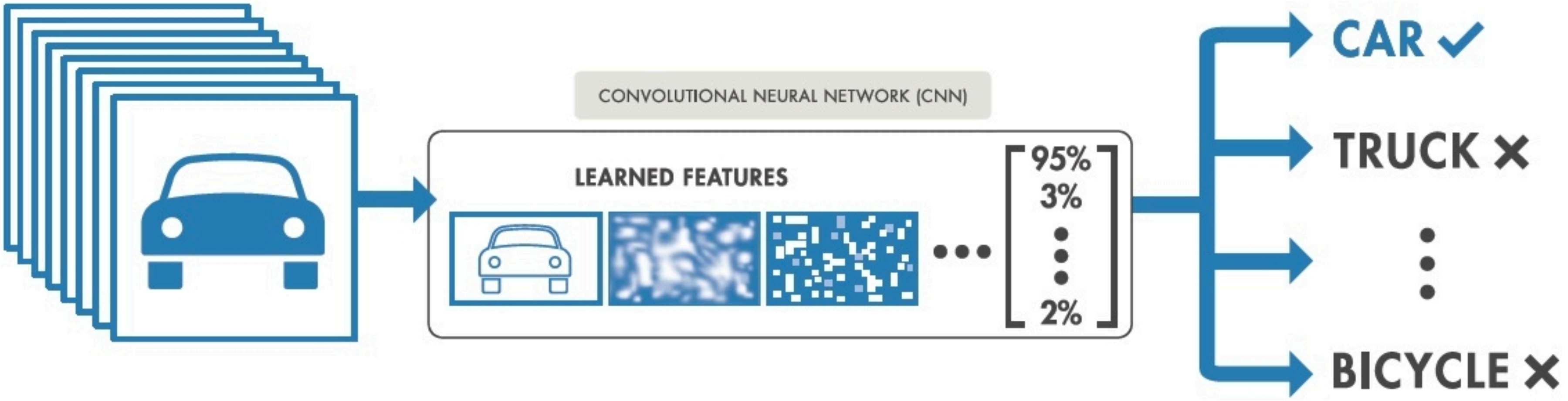
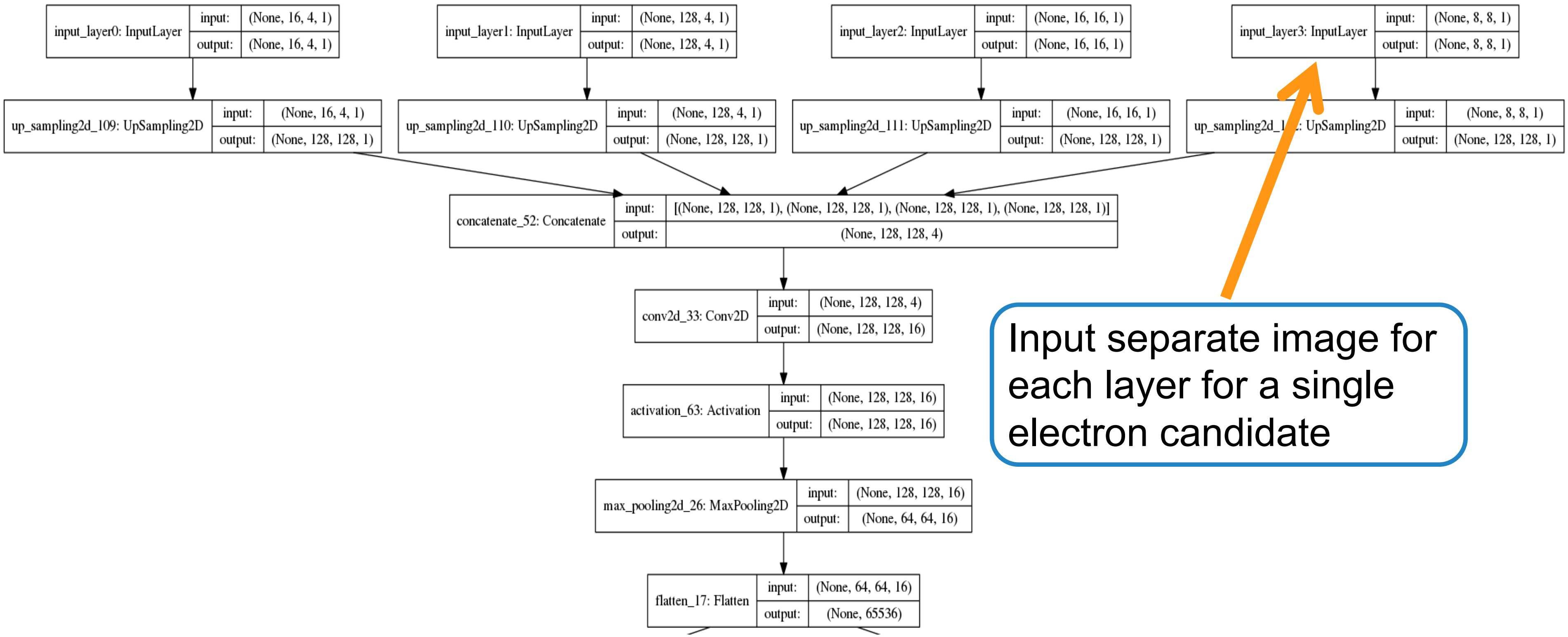
- Different filters learn different features/aspects of the image



CNNs for Electrons

Initial architecture design utilizing all 4 layer images



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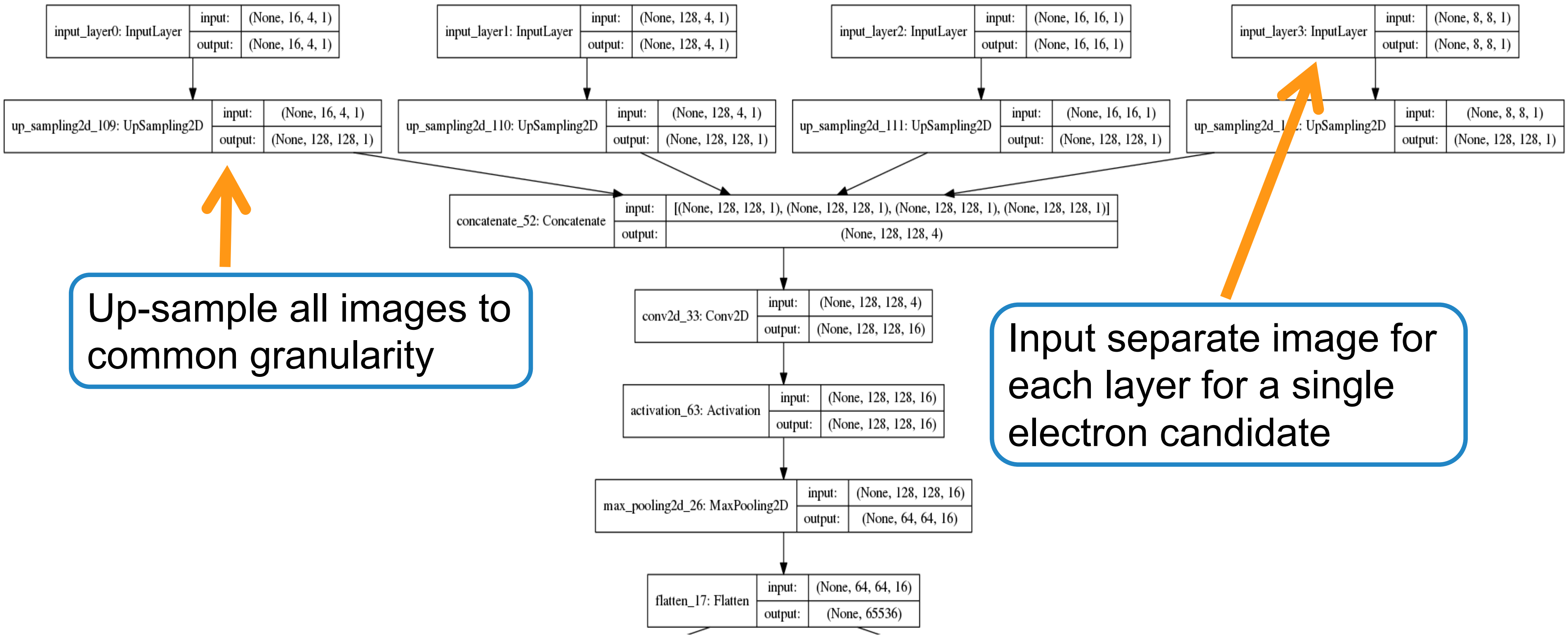

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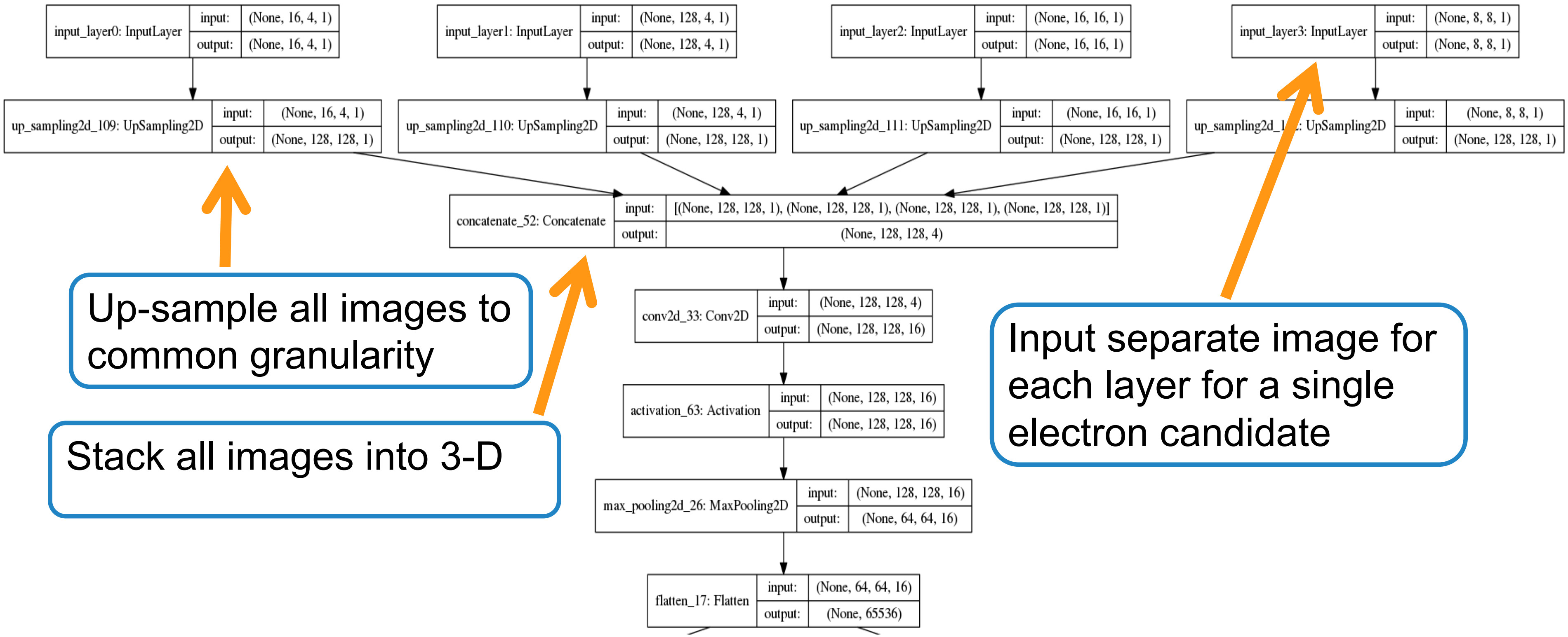

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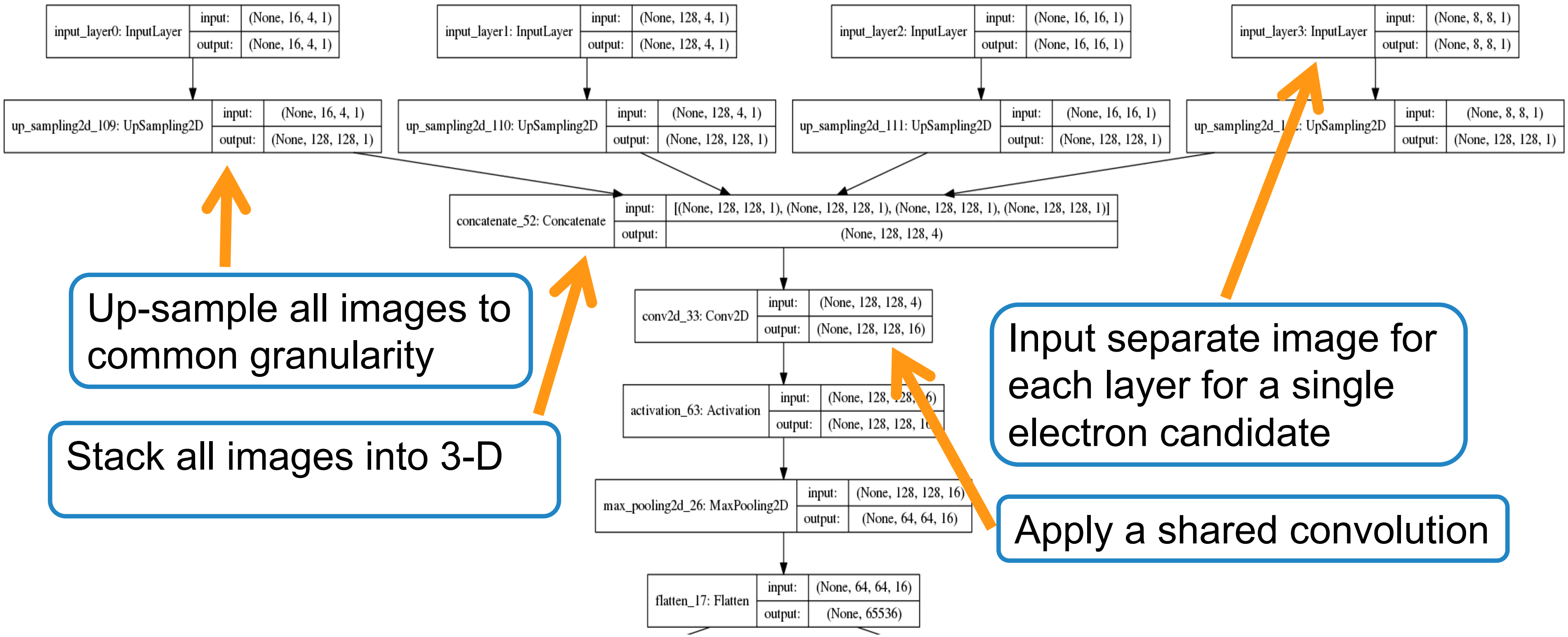

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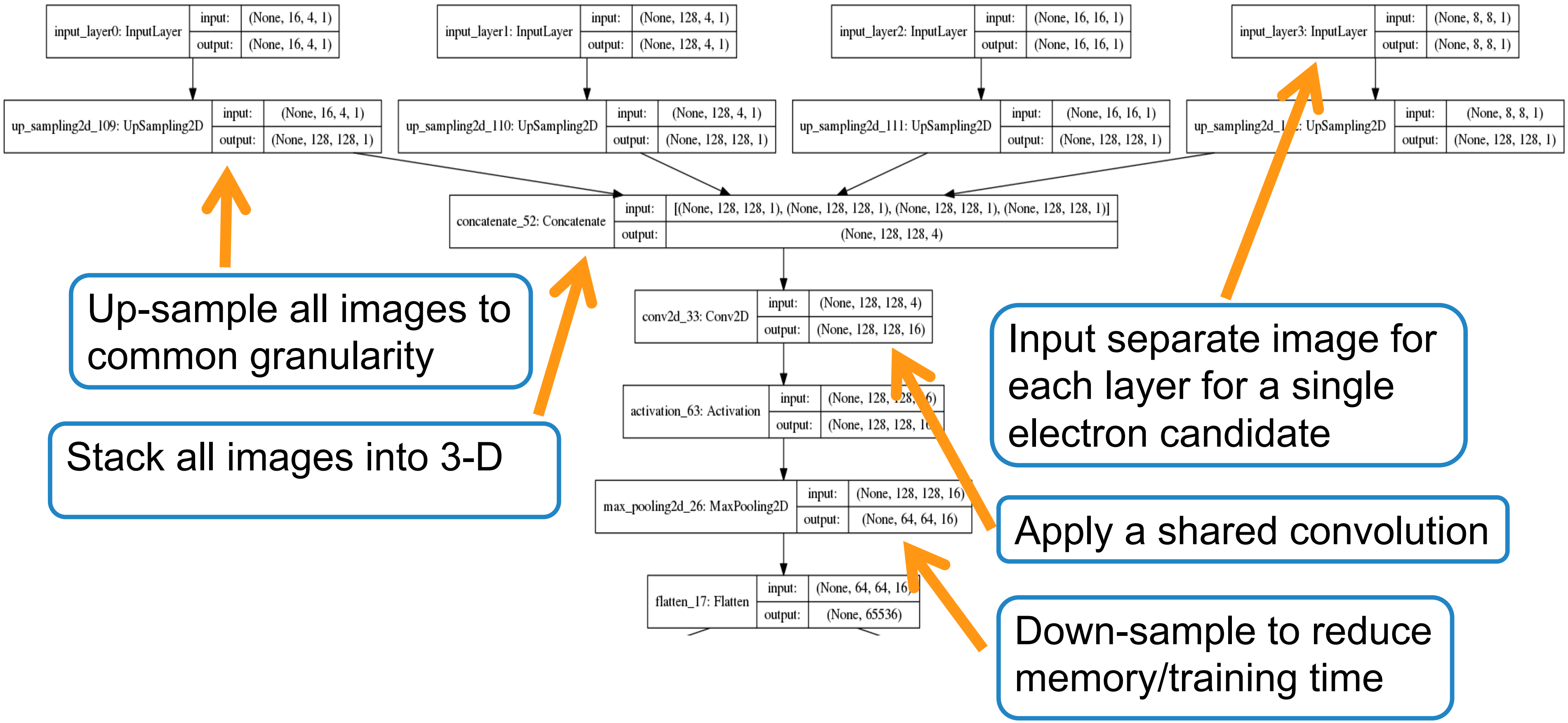

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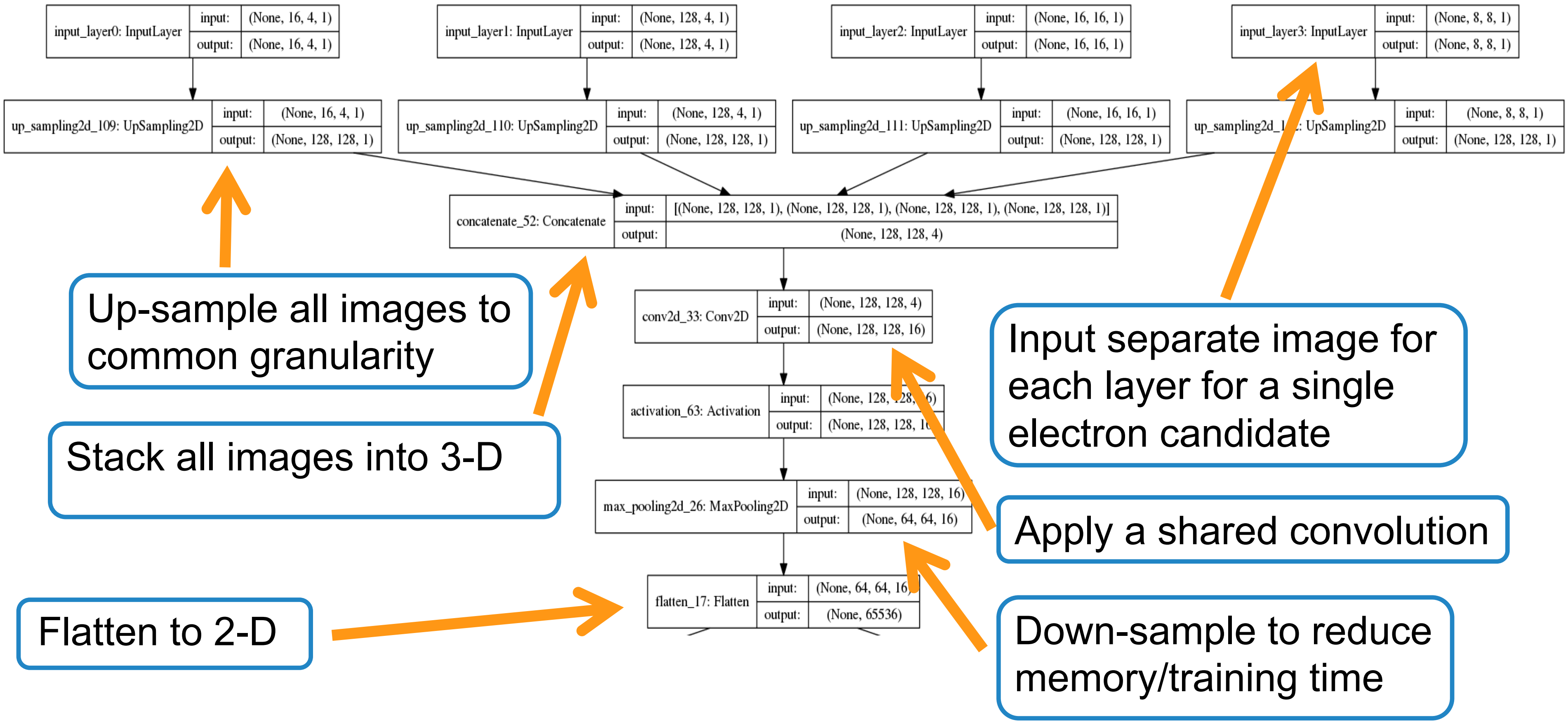

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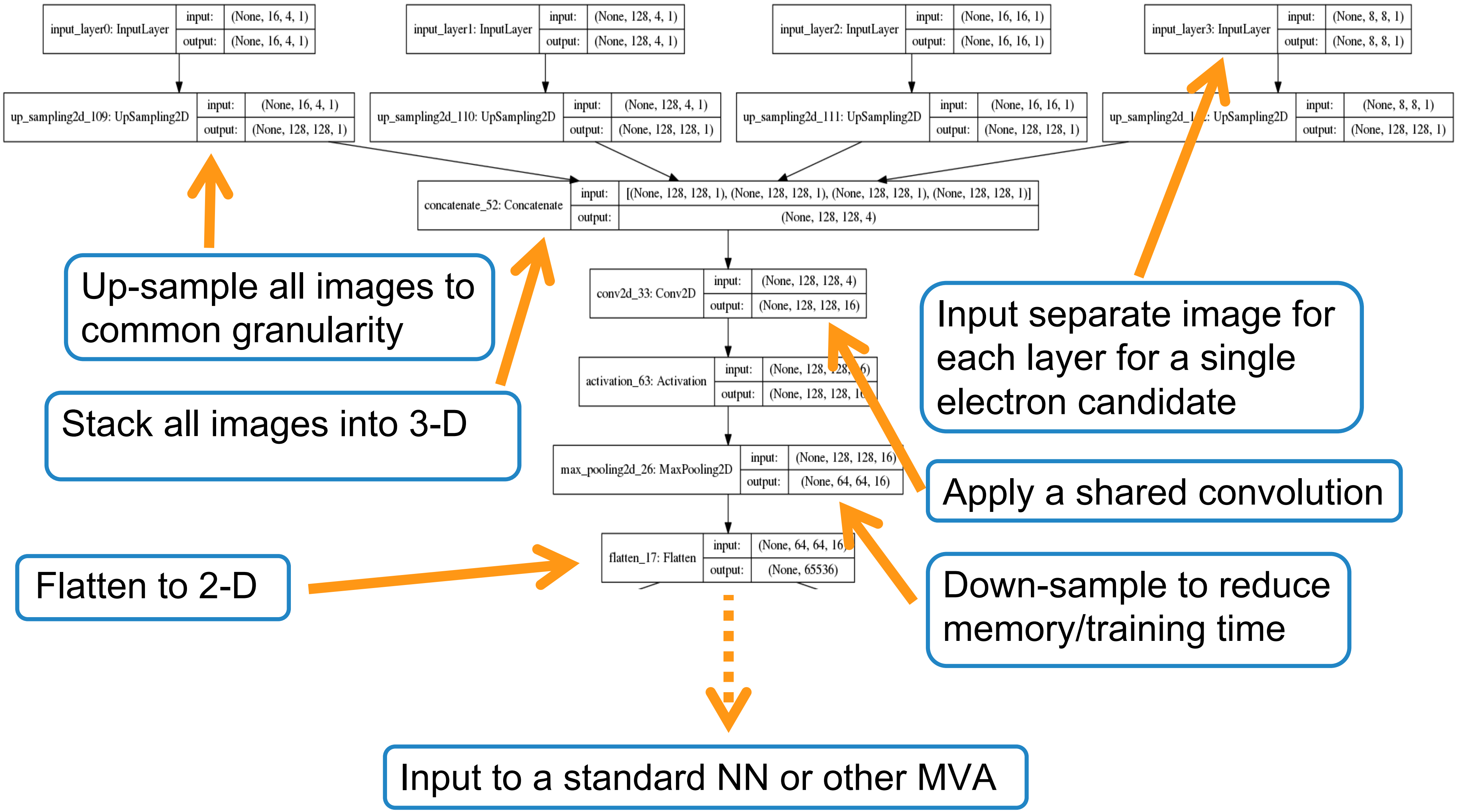
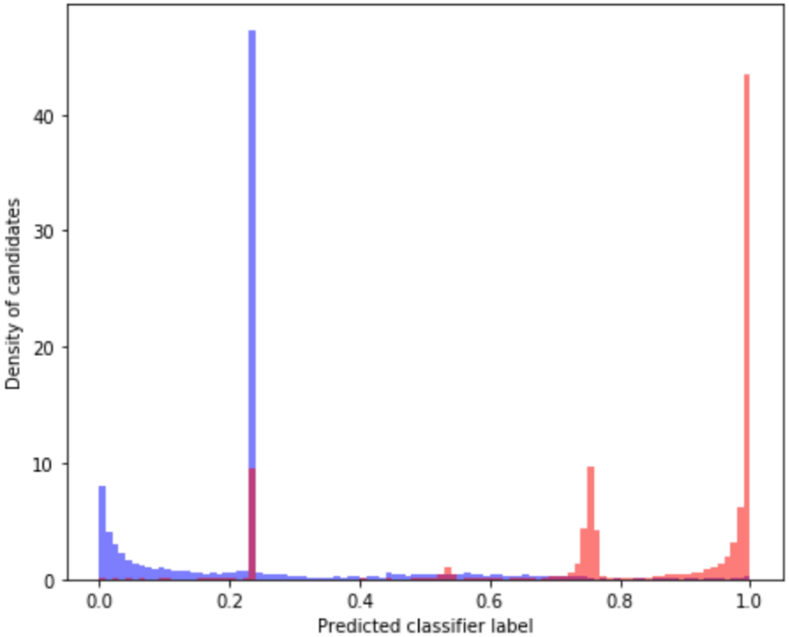


CNNs for Electrons

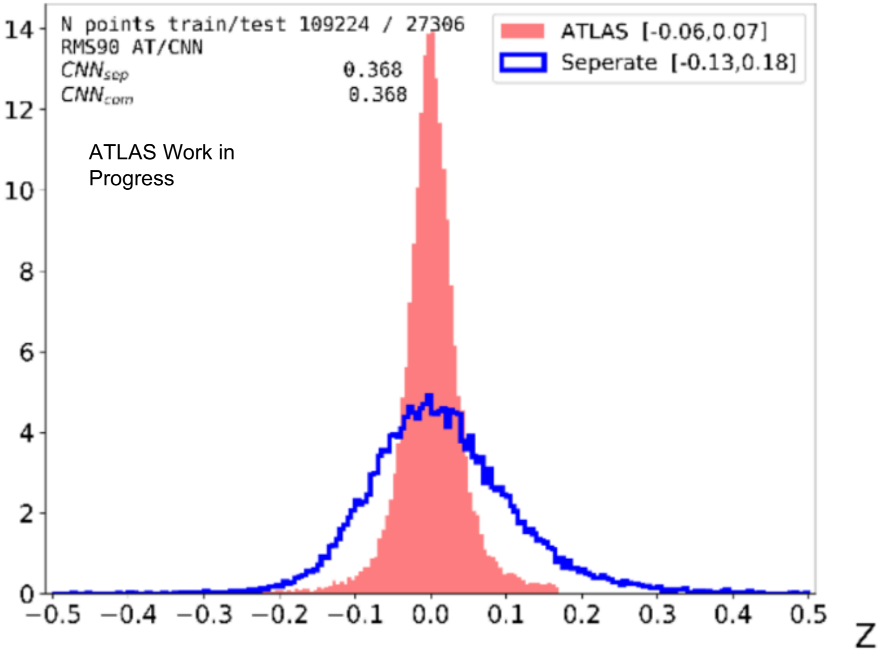
IDENTIFICATION

- Input processed images to a fully-connected NN
- Train NN for binary-classification: electrons=1 background=0
- Promising results with simple design and no tuning!



REGRESSION

- Input processed images to a fully-connected NN
- Train NN to produce scale-factor to apply to reconstructed energy
- Not so great results….37% of ATLAS performance



On-going Work

- Consider other architectures:
  - Separate convolutions for each layer (no need to up-sample)
  - 3D convolution (allows network to learn relationship between layers)
- Optimize hyper-parameters and network design
- Explore options for including track information
  - Add variables to fully connected DNN
  - Create track images by projecting hits into 2-D plane
- Evaluate feasibility of training on data
  - Purity is a concern for data samples, but accurate modeling is a concern for MC
  - Can also use GAN to create better simulations
- Exciting results to come!

Thanks!
Any questions?

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